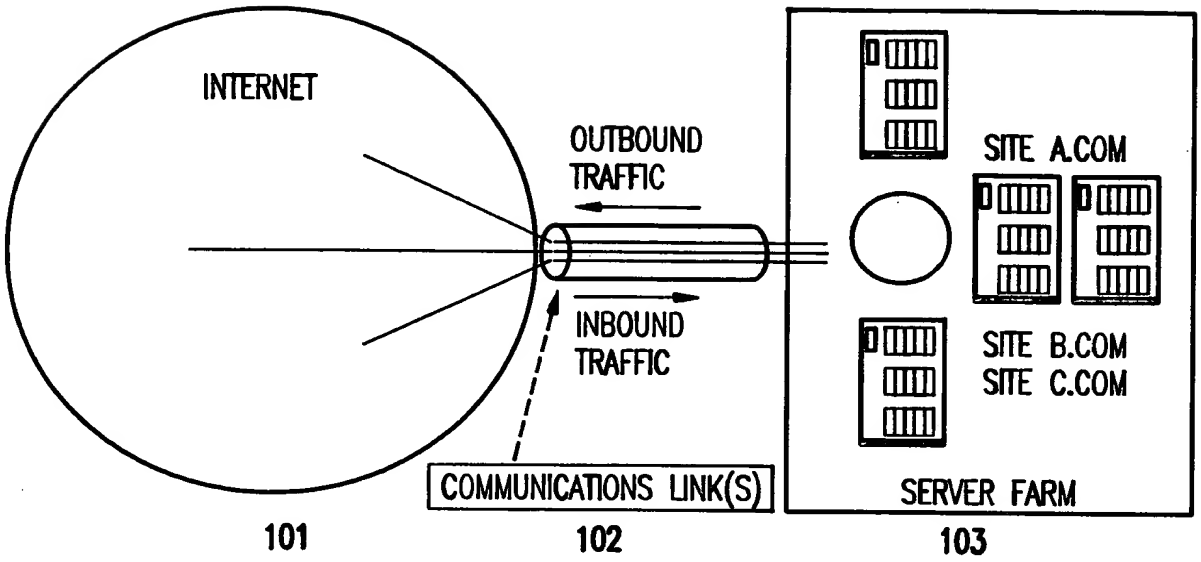
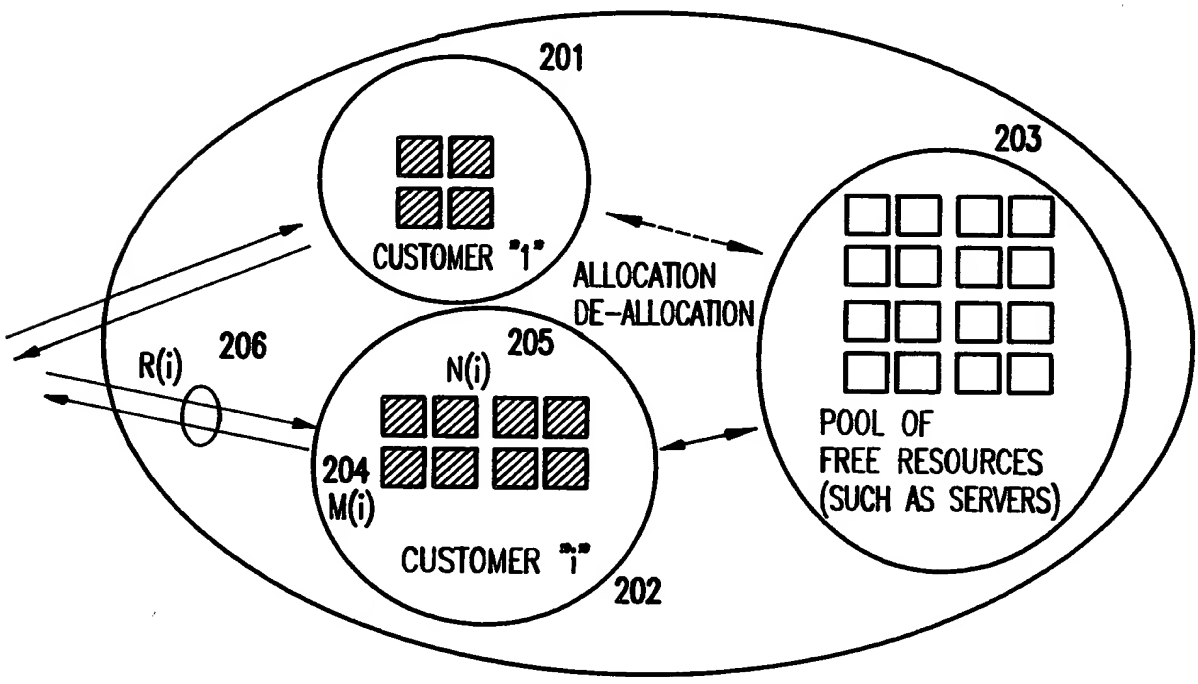


FIG.1



MEASURE R(i), N(i), AND M(i)
COMPUTE Nt(i) AND Rt(i) FROM Mt(i), R(i), N(i) AND M(i),
AND THEN IF NEEDED, MOVE M(i) TO Mt(i) BY EITHER CHANGING N(i)
TO Nt(i) OR CHANGING R(i) TO Rt(i).

FIG.2

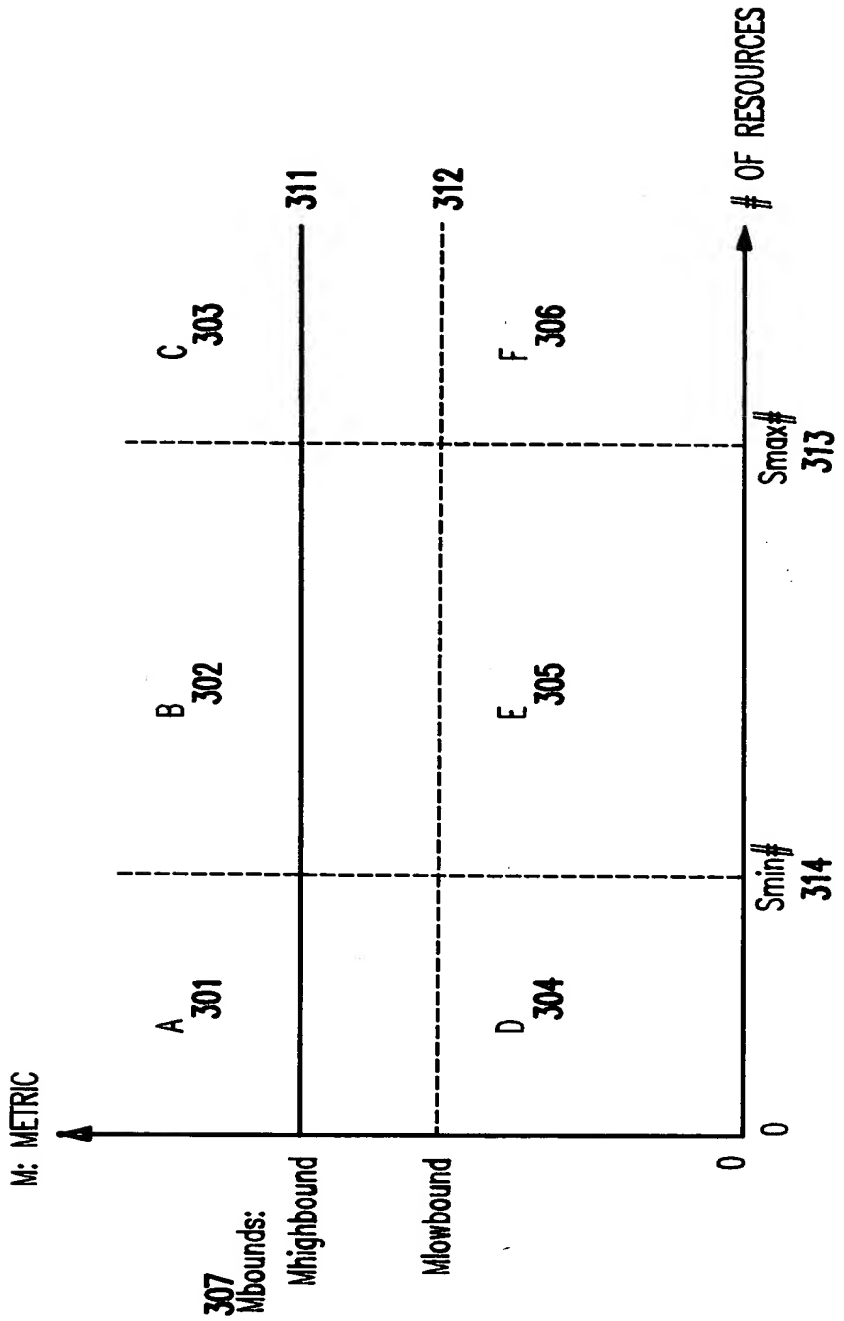


FIG.3

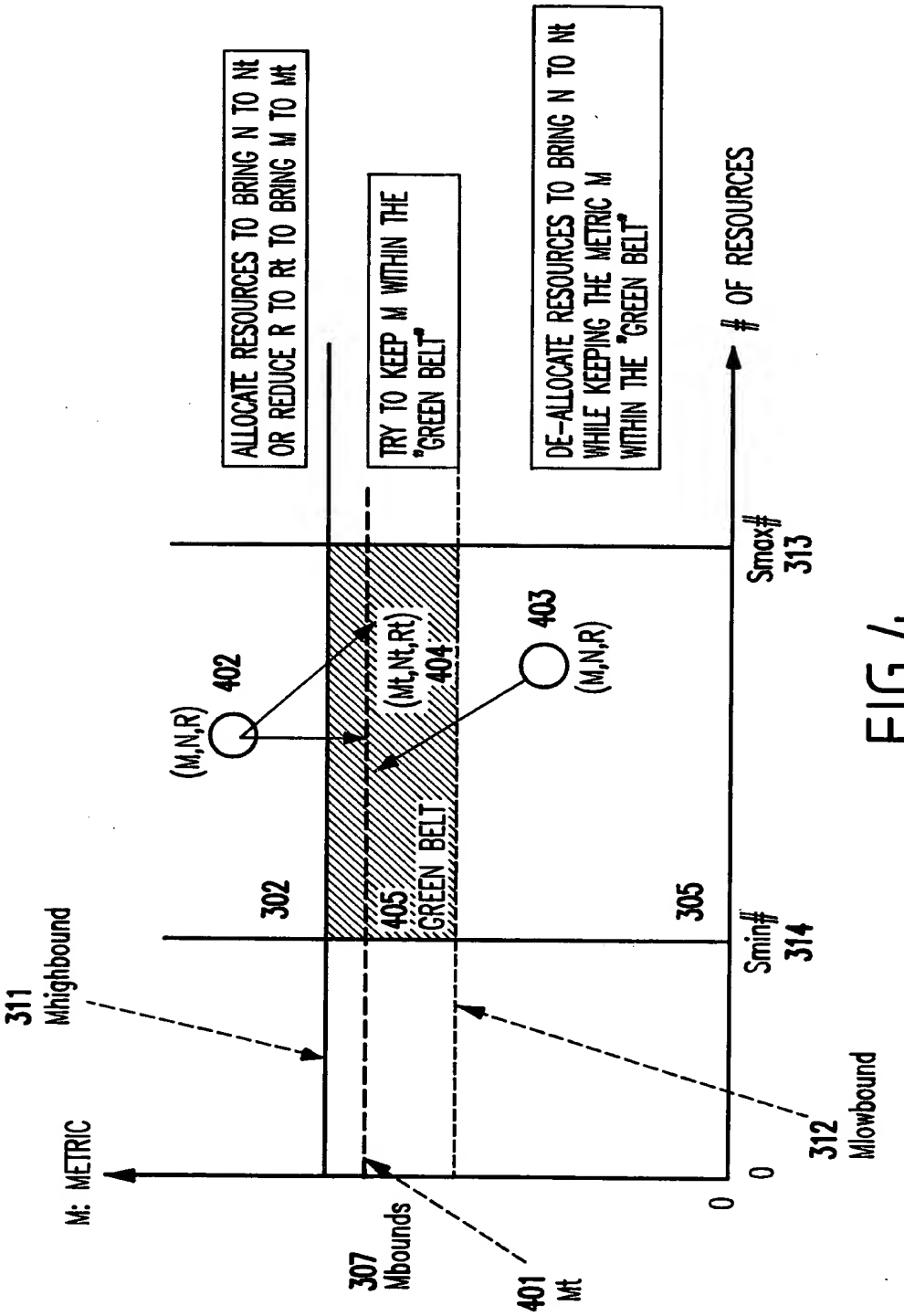


FIG.4

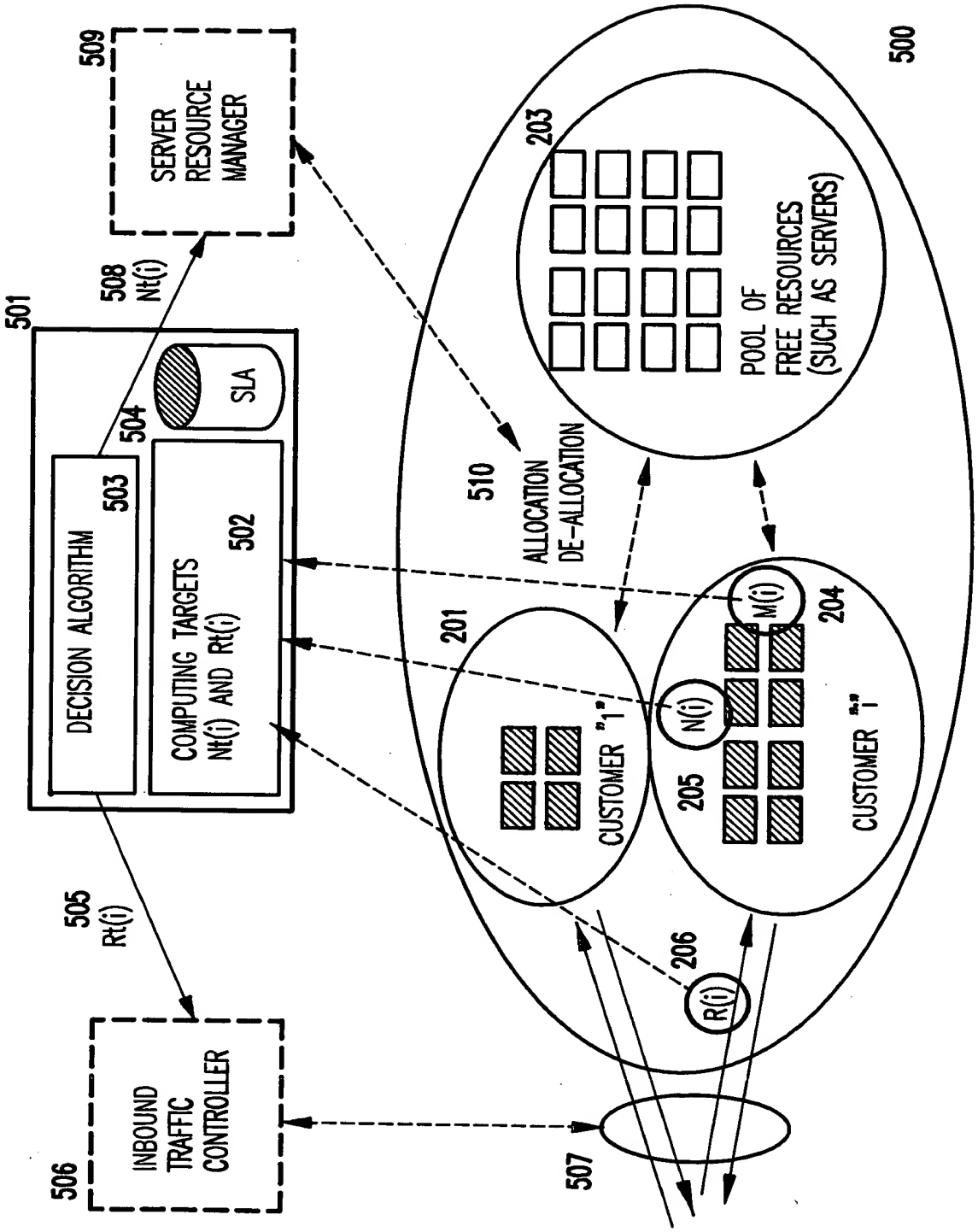


FIG.5

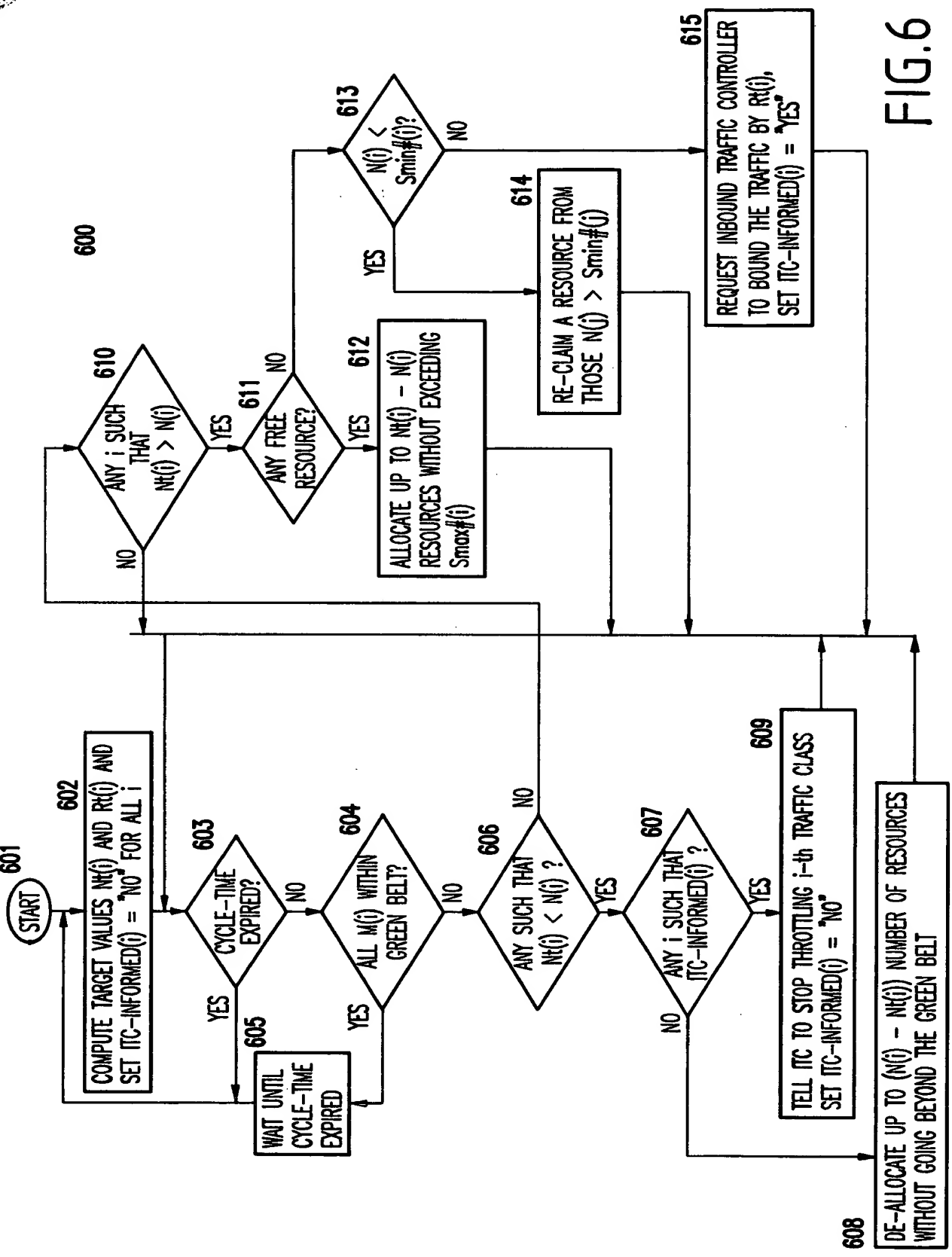


FIG.6

Smin#(i)	: the amount of resources guaranteed for the i-th customer. This can be a vector.
Smax#(i)	: the maximum amount of service resources that could be made available to the i-th customer. This can be a vector.
Mbounds(i)	: the bounds on the service level metric. Each "bounds" consists of a pair, "highbound" and "lowbound."
Ubounds(i)	: the bound on the utilization of resources allocated to the i-th customer
Tbounds(i)	: the bound on the agreed upon average server response time for the i-th customer
T%bounds(i)	: the bound on the agreed upon server response time percentile for the i-th customer
(Smin#(i),Smax#(i),Mbound(i))	: the SLA supported by the invention
N(i)	: the number (or amount of) of resources currently allocated to the i-th customer.
R(i)	: the current inbound traffic rate for the i-th customer. This could be a vector when more than one type of traffic is defined for each customer.
M(i)	: the current value of the metric M for the i-th customer. This could be a vector. Examples are: **U(i)** : the current utilization of the allocated resources to the i-th customer; **T(i)** : currently observed server response time averaging for the I-th customer; **T%(i)** : currently observed server response time percentile for the I-th customer
Mt(i)	: the "target" (want to achieve) metric value for the i-th customer. Its dimension is same as the dimension of M(i). This is within the defined "green belt" which is the region within which M(i) is kept. Examples of Mt(i) are: **Ut(i)** : the target resource utilization when M = U, **Tt(i)** : the target average response time when M = T; **Tt%(i)** : the target percentile response time when M = T%

Table 1

REPLACEMENT SHEET

For Utilization as Metric: M = U and Mt = Ut

The following relationships hold among various variables:
U(i) = C(i)R(i) / N(i), where C(i) is a constant
Ut(i) = C(i)R(i) / Nt(i), and
Ut(i) = C(i)Rt(i) / N(i).

From the above and from the given values of N(i), R(i), U(i), and the target value Ut(i), Nt(i) and Rt(i) can be computed as follow:

Nt(i) = CEILING [N(i)U(i) / Ut(i)], and
Rt(i) = FLOOR [R(i)Ut(i) / U(i)],

where CEILING gives the smallest integer exceeding and
FLOOR gives the largest integer not exceeding.

Table 2

For Average Response Time as Metric: M = T and Mt = Tt

S(i) :server "service" (or processing) time for the i-th customer, this can be computed from observing each individual server service time, or estimated from a queueing formula:

S(i) is a function of {T(i),R(i),N(i)}
If the cluster of servers is modeled by the M/M/m queueing system,
S(i) = ((R(i)T(i)+N(i)+p{N(i)}) - SQRT((R(i)T(i)+N(i)+p{N(i)})**2 - 4R(i)T(i)R(i) / 2R(i)
where p{m} is the probability that there are m requests in the i-th customer's server cluster

For the M/M/m queuing model,

$$Tt(i) \sim S(i) + p\{Nt(i)\}S(i) / (Nt(i)-R(i)S(i))$$

$$Tt(i) \sim S(i) + p\{N(i)\}S(i) / (N(i)-Rt(i)S(i))$$

Therefore,

$$\mathbf{Nt(i)} = \text{CEILING } [R(i)S(i) + p\{Nt(i)\}S(i) / (Tt(i)-S(i))]$$

$$\mathbf{Rt(i)} = \text{FLOOR } [N(i)/S(i) - p\{N(i)\}/(Tt(i)-S(i))]$$

where p{m} is the probability that there are m requests in the customer's server cluster

Table 3

REPLACEMENT SHEET

For Percentile Response Time as Metric: M=T% and Mt=Tt%

If T%(i) > T%bound(i), then the average response time T(i) needs to be reduced by (T%(i) - T(i)). Therefore, for T%(i) to approach T%bound, the average response time target Tt(i) becomes:

$$Tt(i) = T(i) - (T\%(i) - T\%bound(i)).$$

For the M/M/m queueing model,

$$Tt(i) \sim S(i) + p\{Nt(i)\}S(i) / (Nt(i)-R(i)S(i))$$
$$Tt(i) \sim S(i) + p\{N(i)\}S(i) / (N(i)-Rt(i)S(i))$$

and thus,

$$\mathbf{Nt(i)} = \text{CEILING } [R(i)S(i) + p\{Nt(i)\}S(i) / (Tt(i)-S(i))]$$
$$\mathbf{Rt(i)} = \text{FLOOR } [N(i)/S(i) - (p\{N(i)\}/Tt(i)-S(i))]$$

where p{m} is the probability that there are m requests in the customer's server cluster

Table 4

REPLACEMENT SHEET

For any given metric M,

There are quick simulation tools, quick numerical computation tools and other approximation formula are available in computing **Nt(i)** and **Rt(i)** from given (i.e., measured) values of R(i), N(i) and M(i).

Table 5